SYNOPTIC FEATURES ATTENDING THE HEAVY RAINS IN THE MIDDLE ATLANTIC STATES AND SOUTHERN NEW ENGLAND, OCTOBER 13–17, 1955

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1. INTRODUCTION

The storm of October 13–17, 1955, which brought heavy rains to the Middle Atlantic States and produced floods, notably in southern New England, is of major interest following so closely the disastrous August floods in New England in the wake of hurricane Diane. Although the heavy rains and floods with the October storm were not as catastrophic as with Diane, they reached major proportions in the same, heavily populated, industrial area not yet recovered from the earlier floods [1, 2].

It is proposed in this article to illustrate this storm, showing the features contributing to the situation and to discuss some of the mechanisms which produced the heavy rains. Of primary interest, is the blocking feature that existed at the time and the deep moisture emanating as it did from a cyclonic development off the east coast of Florida.

2. SURFACE FEATURES

On October 12, 1955 an area of below normal pressure formed over Cuba and its adjacent waters. This depression remained in relatively the same position until it was dissipated on October 15, 1955, with the passage of a cold front moving through the area from the northwest. On October 13, 1955, a center of low pressure formed to the north of this depression in a position approximately 125 nautical miles to the east of Daytona Beach, Fla. (fig. 1). This low deepened and moved to the northeast in advance of a trough of low pressure. This trough extended southeastward from a stagnating Low located in Canada to the north of the Great Lakes. By 1230 GMT, October 14, the Atlantic Coast Low was centered about 60 nautical miles northeast of Cape Hatteras, N. C., and had a central pressure of 995 mb. At this point the Low was moving into an area of increasing southeasterly flow and it recurved toward the northwest moving up the Delaware Bay and through central Pennsylvania. By 1230 GMT, October 15 the Low had moved into extreme southern Ontario, Canada, where it stalled and filled.

The rain area was clearly identified with the system of fronts which existed during the storm (figs. 1, 2). A persistent High in the Labrador region was attended by an extensive flow of polar air moving southward and westward across the Canadian Maritime Provinces. This flow maintained a sharp front separating the tropical and polar air. The front remained stationary just south of Long Island and thus provided a persisting lifting mechanism. Meanwhile the dry polar air to the west advanced steadily southeastward across Florida and the Bahamas, but in the Northeastern States the advance was slowed by the easterly flow attending the blocking High. This led to an occluded system which provided an excellent upslope structure that remained nearly stationary over the area of heavy rains. The easterly flow was further strengthened by the intensification and retrogressive movement of a cyclone to the southeast of the blocking High (fig. 1).

3. THE HEAVY RAIN AREA

The largest amounts of rain fell in western Massachusetts, western Connecticut, and southeastern New York (fig. 2). Point rainfall amounts in the above area were as great as 15 inches for the storm. Heavy rain fell over a large additional area which included southern New England, most of New York, central and eastern Pennsylvania, New Jersey, Maryland, and much of eastern Virginia.

4. THE MOISTURE PATTERNS

An analysis of the moisture patterns which occurred during the storm clearly showed the source region as the tropical Atlantic Ocean in the general vicinity of the Bahama Islands. Precipitable water amounts for the period of the storm were computed, following Solot and Showalter [3, 4], for available radiosonde data at 0300 GMT and 1500 GMT. The isopleths of precipitable water for each 0.50-inch interval were then transferred to the corresponding surface charts (fig. 1). From these charts it is seen that the moist tongue moved northward and in advance of the small Low which originated off the Florida East Coast. Further, that the moisture was carried strongly northward and northwestward into the

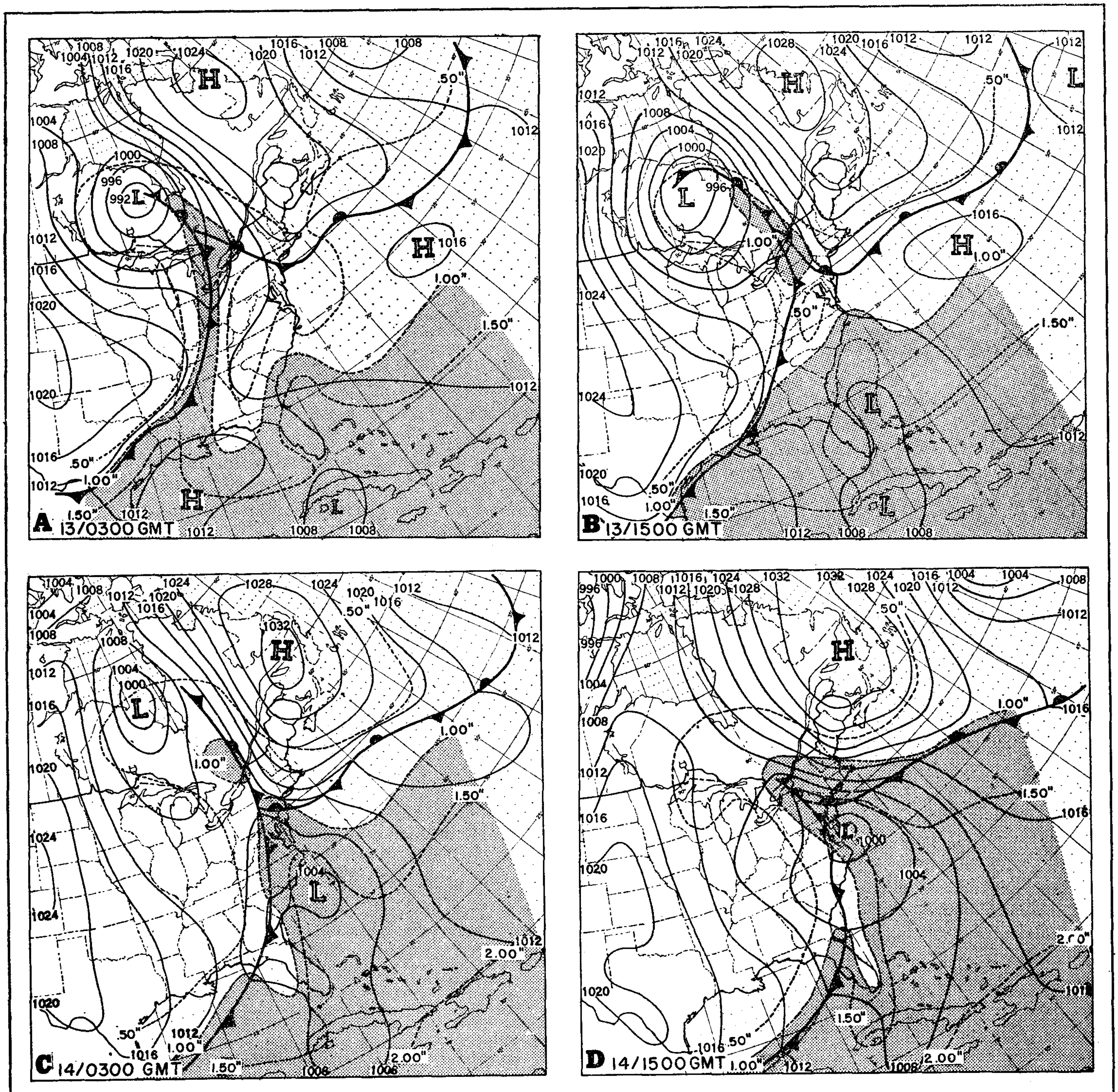

FIGURE 1.—Surface charts at 12-hour intervals 0330 GMT and 1530 GMT, October 13–16, 1955. Isopleths of precipitable water (dashed lines) with an interval of 0.50-inch are superimposed. Shaded areas indicate 1 inch or more of precipitable water. Note the northward progress of moisture associated with the Atlantic Coast Low into the region of the occluded front.

occluded frontal structure for an extended period of time. It also seems reasonable to conclude that the nature of the circulation attending the low pressure system, which had many tropical characteristics, insured favorable conditions for the production of heavy rain. At 1500 GMT, October 15, the computed precipitable water at Hempstead, N. Y., was 1.86 inches. This value, although less than the maximum of record observed for the station [5], is comparable to the mean value occurring in southern Florida in October. The moist tongue was carried northwestward by the strong flow aloft resulting in heavy rain as far west as Buffalo, N. Y.

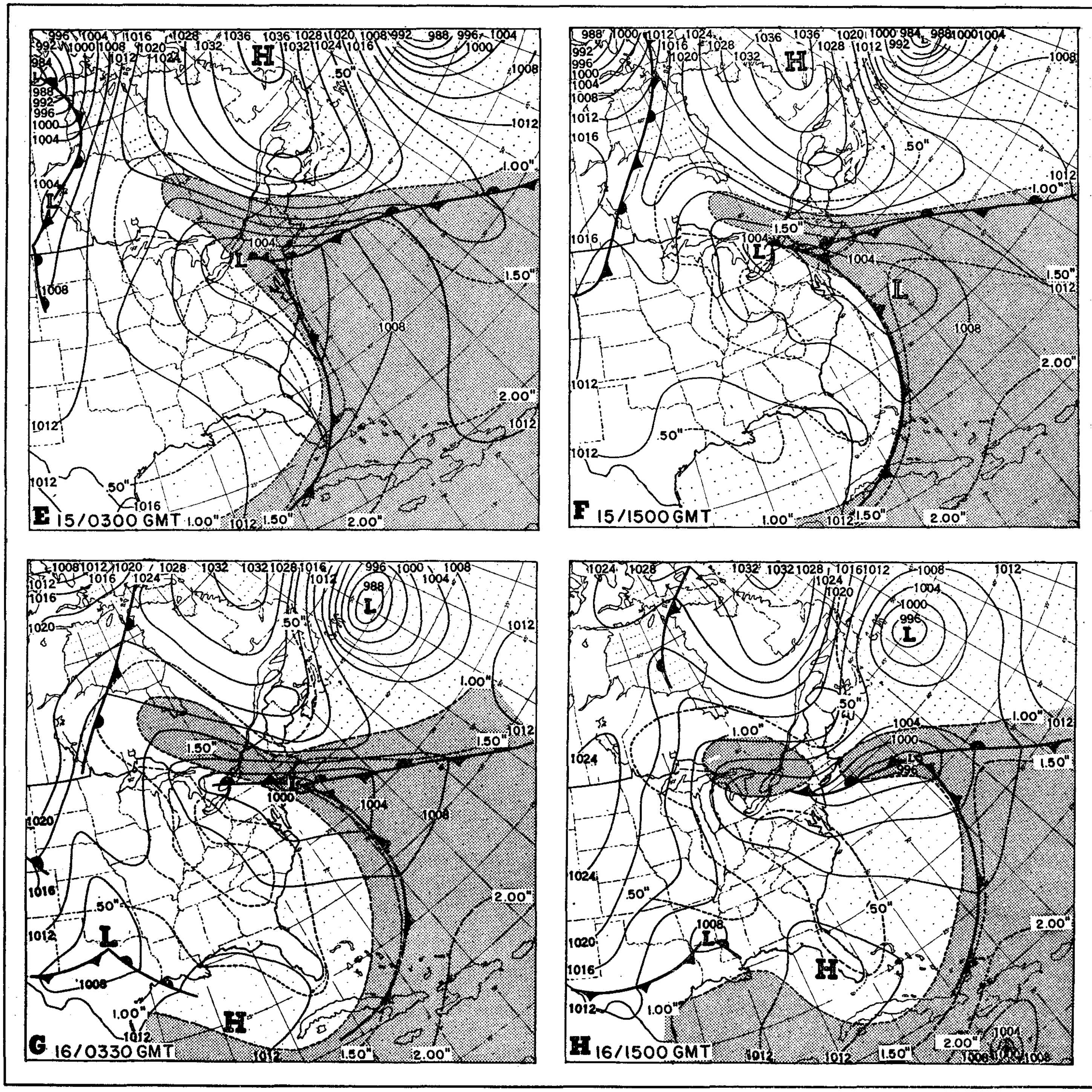

FIGURE 1—Continued.

5. UPPER AIR FEATURES

The period October 13–17 was characterized by strong southerly to southeasterly flow at all tropospheric levels over the region of heavy precipitation. This flow was associated with the broad-scale upper air features persisting throughout the period. A strong blocking High was centered over Labrador as evidenced at the surface and the 500-mb. levels (figs. 1, 3, 4). At the 500-mb. level on October 11, 1955 a large anticyclone was centered over Tennessee and northern Georgia. A developing ridge extended northward from the High to Hudson Bay.

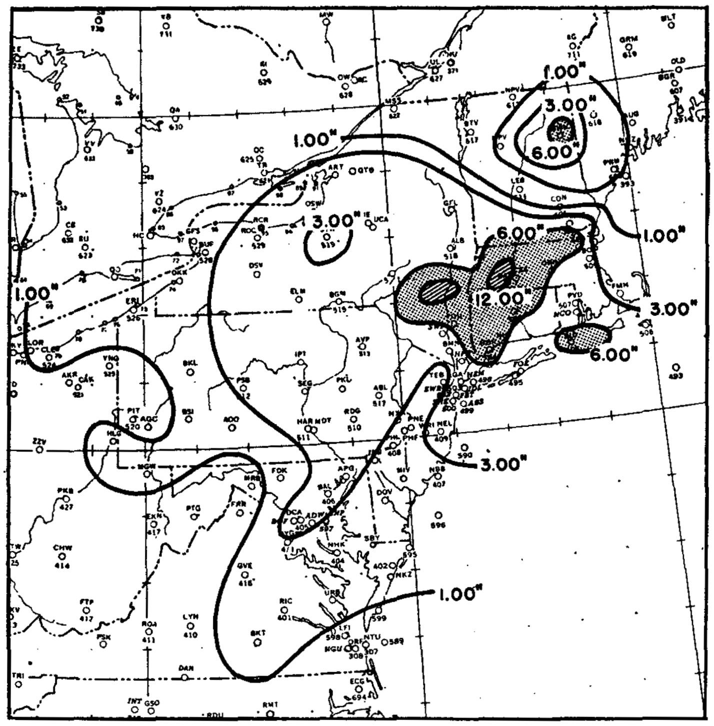

FIGURE 2.—Isohyet chart for the storm October 13–17, 1955, based upon preliminary data. Extreme amounts reported were 15.03 inches at Elka Park, N. Y., and 13.85 inches at Cobble Mountain Reservoir, west of Westfield, Mass.

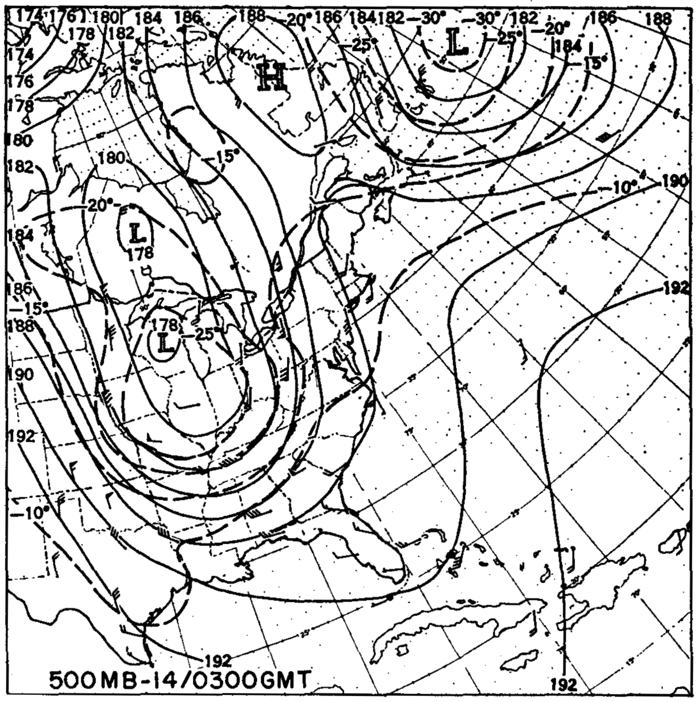

FIGURE 3. 500-mb. chart for 0300 GMT, October 14, 1955. Height contours (solid lines) are labeled in hundreds of geopotential feet and are drawn for 200-ft. intervals. Isotherms (dashed lines) are drawn for intervals of 5° C.

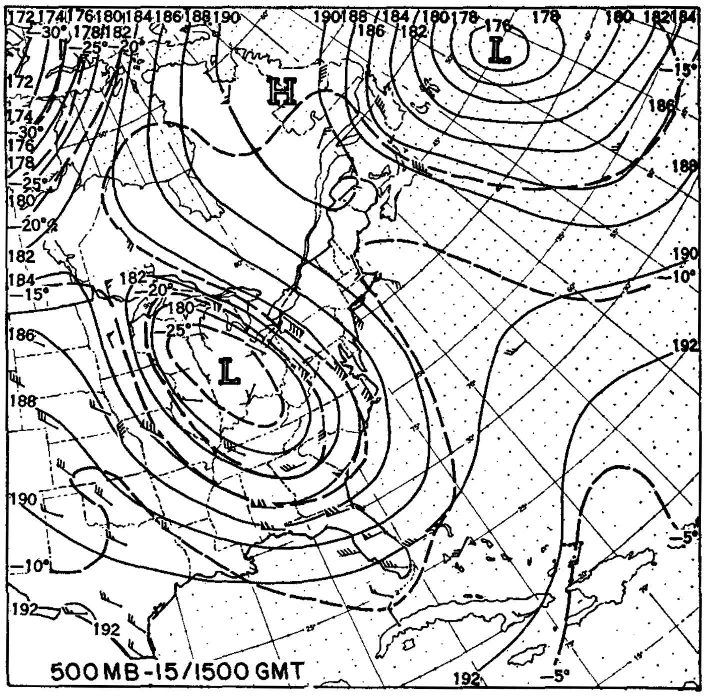

FIGURE 4.—500-mb. chart for 1500 GMT, October 15, 1955.

Another anticyclone was drifting slowly westward from the Davis Strait. The ridge to the west continued to develop and progress toward the east. By October 12, the ridge had consolidated with the westward-moving anticyclone and was centered over northern Quebec. During the next 24 hours the High moved toward the east until it reached Labrador on October 13, and there it became almost stationary. After reaching the stationary position the High increased in magnitude and remained centered over Labrador until October 17, 1955, at which time it began to weaken and move toward the east.

Of equal importance in the contribution to the rain situation, were the events taking place both upstream and downstream from the blocking High. The region immediately upstream from the High was characterized by increasing cyclonic activity. By 0300 GMT, October 14 (fig. 3), a trough at the 500-mb. level was oriented north-south extending from northern Canada to the Gulf of Mexico. In this trough an elongated cut-off Low, having a double center, extended from the southern portion of Hudson Bay to southern Illinois. One center of this Low was located southeast of Trout Lake, Ontario, and the other center was located to the west of Green Bay, Wis. A short-wave-length trough associated with the Atlantic Coast Low extended from Wilmington, N. C., to Cuba. By 1500 GMT, October 15 (fig. 4), the Low at 500 mb. was centered near Toledo, Ohio, with a trough oriented northwest-southeast. A zone of strong southsoutheasterly flow extended from the Carolinas into Canada. The axis of the trough line continued to back as the flow on the rear side of the trough became more westerly, with the axis of the trough line assuming more and more of a west-east orientation. By October 16,

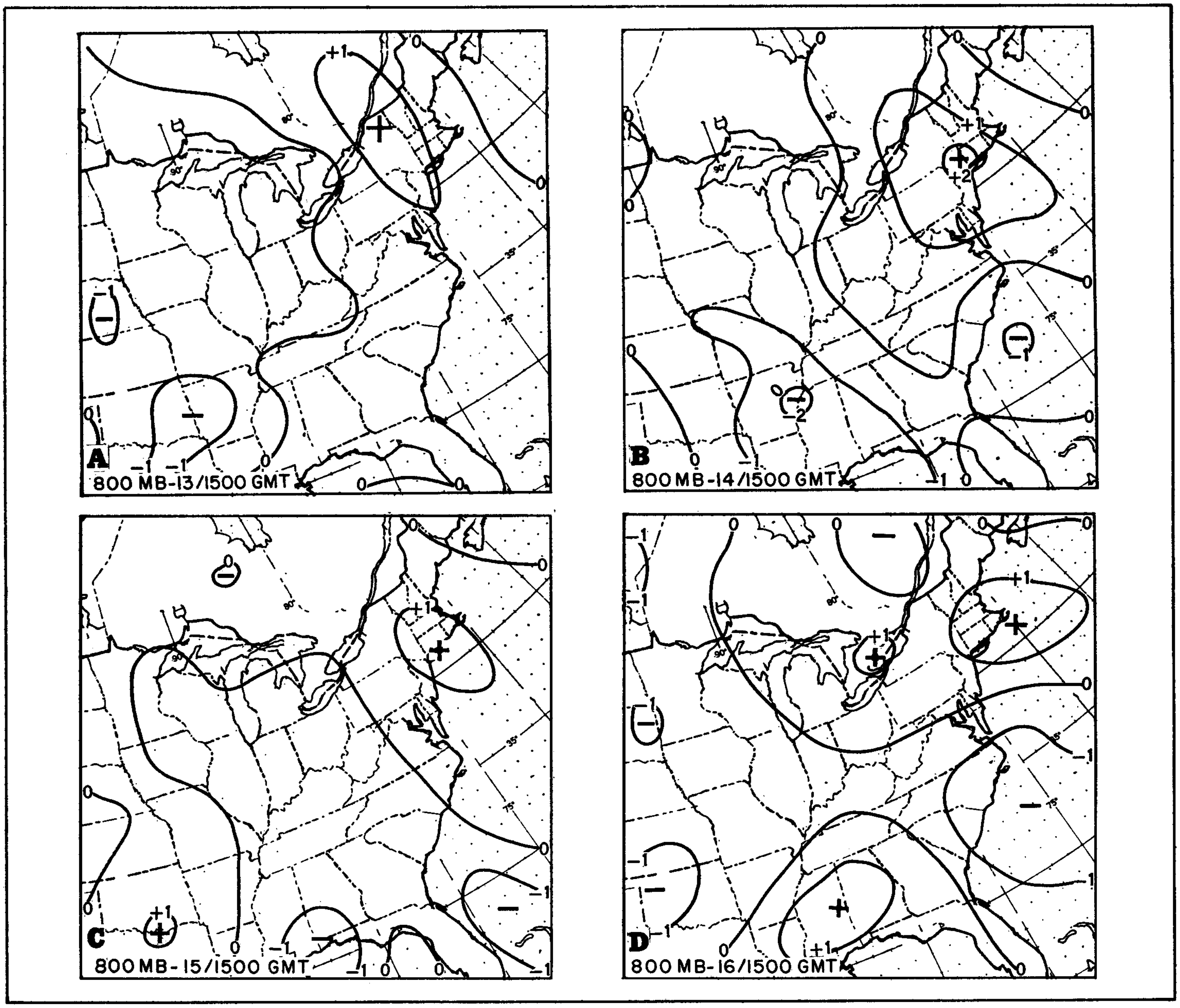

FIGURE 5.—800-mb. vertical velocity (W) charts at 24-hour intervals for 1500 GMT, October 13–16, 1955 based on data furnished by Joint Numerical Weather Prediction Unit. Contours are labeled in units of cm. sec.$^{-1}$. The vertical velocity values are mean instantaneous values for the layer 900 mb. to 700 mb. Positive values indicate ascending motion and negative values, descending motion.

the area of maximum rainfall was under the zone of maximum southeasterly flow aloft.

The region immediately downstream from the blocking High was also characterized by increasing cyclonic activity. A cut-off Low formed in a trough at 500 mb. east of Newfoundland near 41° N., 42° W. This Low developed very rapidly and moved toward the west. For an account of the mean, broad-scale features of the flow during October 1955, the reader is referred to the article by Dunn [6] elsewhere in this issue.

6. VERTICAL MOTION

The subject of numerical prediction of precipitation is presently receiving much attention [7]. The field of vertical motion is an integral part of such predictions and, therefore, is being presented here as a synoptic feature.

Analyses of the mean, large-scale vertical velocities have been prepared from data furnished by the Joint Numerical Weather Prediction Unit. The computed vertical velocities are mean "instantaneous" [1] values for a specific layer. In the case of the vertical motion illustrated by the 800-mb. W chart (fig. 5) the layer extends from 900 mb. to 700 mb. Values shown on the 550-mb. W chart (fig. 6)

[1] "Instantaneous" is used here in a relative sense. The computed values of vertical velocities are mean values over a period of 1 hour centered 30 minutes after the time of the synoptic upper air data. This time period is inherent in the machine method of computation.

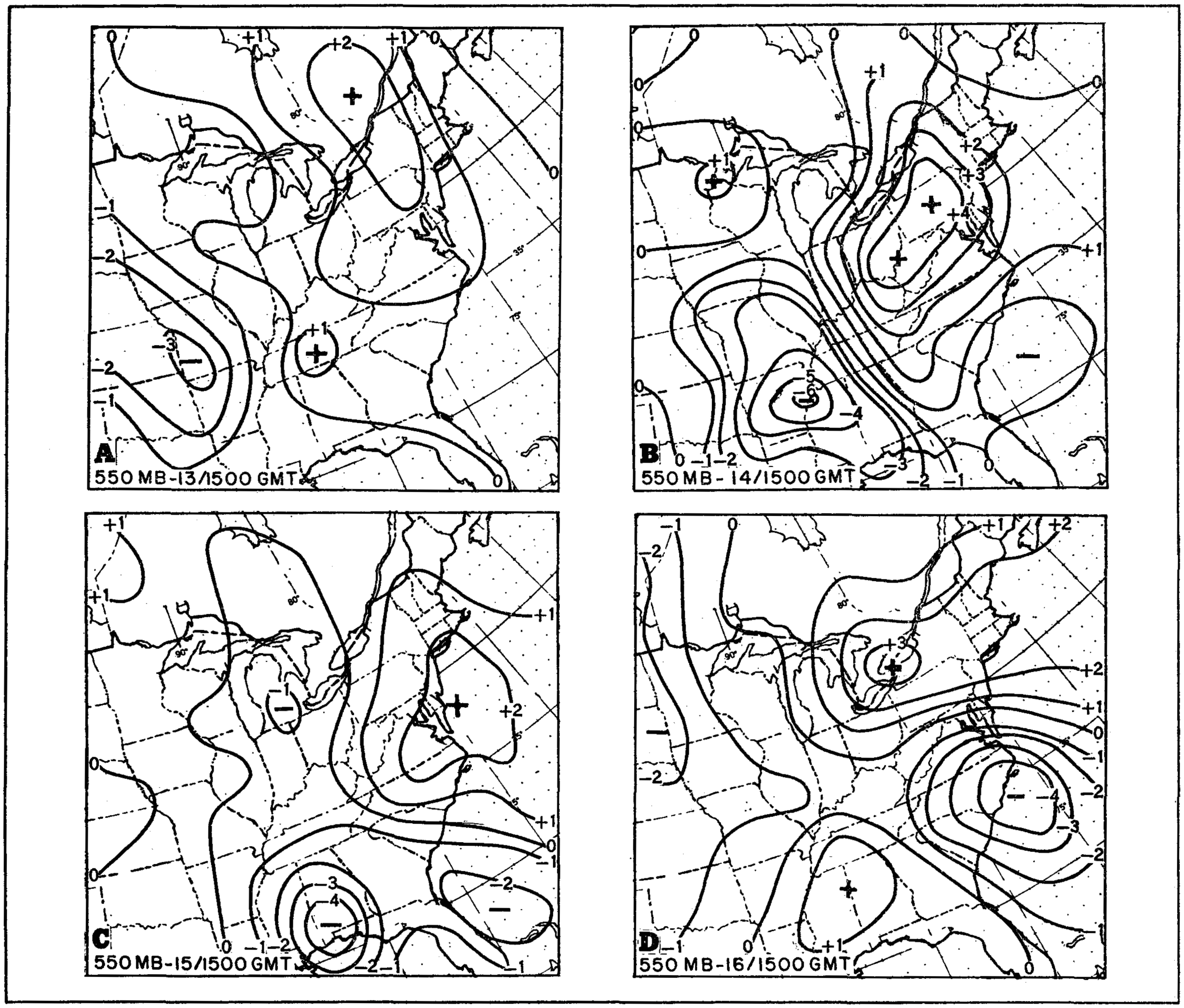

Figure 6.—550-mb. vertical velocity (W) charts at 24-hour intervals for 1500 GMT, October 13–16, 1955 based on data furnished by Joint Numerical Weather Prediction Unit. The vertical velocity values are mean instantaneous values for the layer 700 mb. to 400 mb.

apply to the layer between 700 mb. and 400 mb. Comparison of the charts of vertical velocities with the rainfall and precipitable water charts (figs. 1, 2) shows good qualitative agreement between the area of heavy rainfall and the location of positive vertical motion of very moist air. Quantitative interpretation requires consideration of the grid size used in the computation of the vertical motion and of the local convective and orographic effects.

Following Showalter [8] a computation of rainfall intensity was made using a vertical velocity of 2 cm. sec.$^{-1}$ and substituting other reasonable values in his formula. Showalter's formula for computing point rainfall intensity is

$$I=\frac{W\rho_0(w_0-w_1)}{7}$$

Where I=intensity of rainfall over unit area, in./hr.
W=vertical velocity at condensation level, m. p. s.
ρ_0=air density at condensation level, grams/m.^{3}
w_0=mixing ratio at condensation level, grams/gram
w_1=mixing ratio at top of convective updraft, grams/gram

The Showalter formula assumes the product $\rho_0 W$ to be constant throughout the lifting process; in other words, there is no convergence or divergence. If convergence is

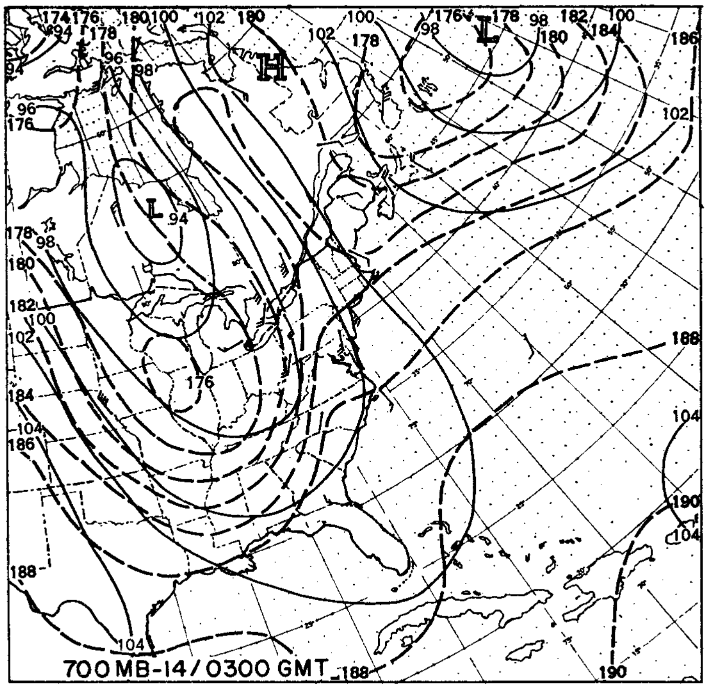

Figure 7.—Temperature advection chart for 0300 gmt, October 14, 1955. 700-mb. height contours (solid lines) and 1000–500-mb. thickness lines (dashed lines) are both labeled in hundreds of geopotential feet and are drawn for intervals of 200 ft.

present the formula must be used in a cumulative step basis. In any computation ρ_0 and W must be selected at the same level since the formula requires the product $\rho_0 W$ be constant for the layer used.

The result of the computation was of the order of 0.05 inch per hour. This intensity as computed here is, of course, applicable to an area of not less than 35,000 square miles since the grid used in the JNWP Unit computations is a square lattice of about 300 km. on a side. As shown by Showalter's "enveloping isohyets of greatest observed depth" [8], point rainfall intensities would be expected to amount to several times the average intensity occurring over an area of several thousand square miles. Also, as pointed out by other authors [7, 9, 10, 11] the effects of local convection and of orographic lifting would not necessarily be revealed by the large-scale field of vertical velocity.

7. WARM ADVECTION

Warm geostrophic advection was a prominent synoptic aspect over the area of heavy rain. In order to illustrate this feature the mean temperature pattern (1000–500-mb. thickness) has been superimposed upon the corresponding 700-mb. contour chart (figs. 7, 8). As can be seen by inspection, warm advection was at a maximum from about Chesapeake Bay to southeastern New York and western Connecticut at 0300 gmt, October 14. By 1500 gmt, October 15, this feature was still at a maximum over western Connecticut and southeastern New York and had

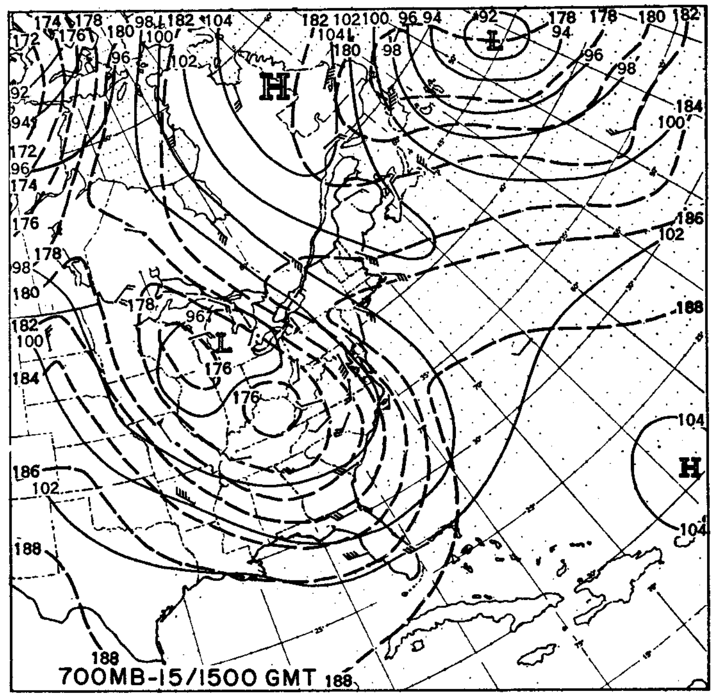

Figure 8.—Temperature advection chart for 1500 gmt, October 15, 1955.

become quite prominent in central and eastern New York where large amounts of rain occurred (fig. 2).

It is noteworthy, that in northern Maine, where rainfall was negligible, cold advection is apparent on both charts. During the 36-hour period 0300 gmt, October 14 through 1500 gmt, October 15, as can be seen in figures 7 and 8, the 18,400-ft. thickness line advanced about 360 nautical miles, or at a rate of about 10 kt. The mean advective wind during the same period was approximately 30 kt. The excess of 20 kt. probably was resolved into large-scale vertical motion. However, because of the complicated relationships between vertical motion and cooling [12] of unstable air it is very difficult to establish a quantitative balance of these factors.

8. OROGRAPHY

The orographic influence with this storm cannot be overlooked. The stations reporting extreme amounts of precipitation were all located at relatively high elevations; for instance, Elka Park, N. Y., which reported 15.03 inches, is high in the Catskill Mountains (elev. 2,250 ft. m. s. l.) and Cobble Mountain Reservoir, west of Westfield, Mass., is in the Berkshire Mountains (elev. approx. 1,000 ft. m. s. l.). It is also interesting to note that Mount Washington, N. H., which was well to the northeast of the area of heaviest precipitation reported 6.31 inches.

9. PRECIPITATION MASS CURVES

The history of this storm can be dramatically summarized by an examination of the precipitation graphs

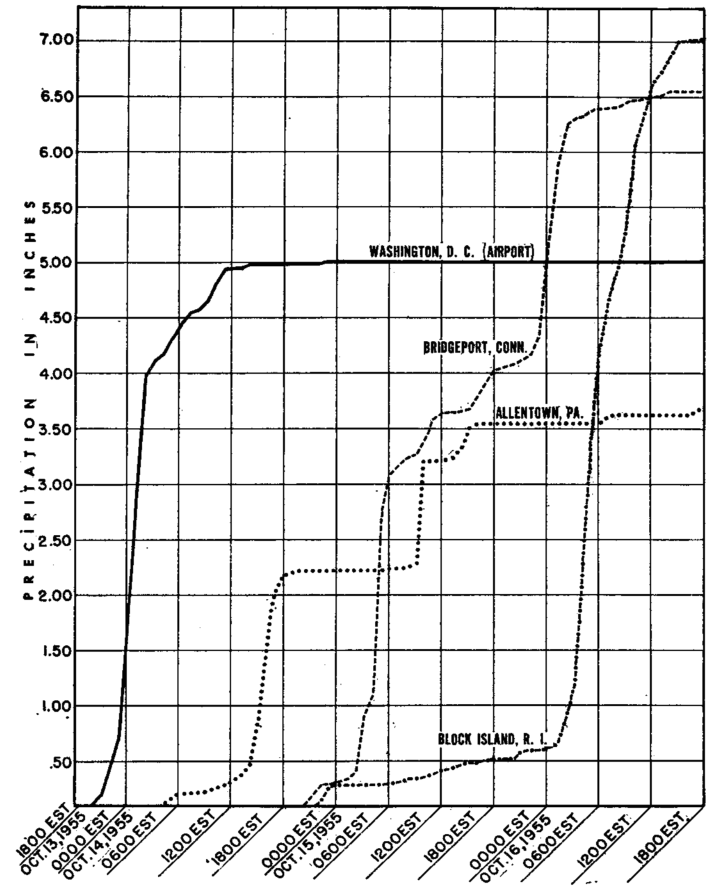

FIGURE 9.—Precipitation graph (mass curves) October 13–17, 1955 for selected stations. Data based upon hourly precipitation amounts as taken from monthly station summaries.

(mass curves) for Washington, D. C., Allentown, Pa., Bridgeport, Conn., and Block Island, R. I. (fig. 9), making cross-reference to the surface charts (fig. 1). The mass precipitation curve for Washington, D. C. shows that a total of 5 inches of rain fell, 3 inches of which fell in one burst between 2300 EST, October 13, and 0200 EST, October 14, 1955. The heavy rainfall at Washington occurred simultaneously with the passage of the cold front moving from the west and the arrival of the deep moist tropical air moving northward with, and in advance of, the Atlantic Coast Low. The rain at Washington was accompanied by intense thunderstorm activity reflecting the unstable conditions in existence at the time.

The mass curve for Allentown, Pa. shows that the total precipitation occurred in two bursts. The first burst between 1400 and 1800 EST, October 14, 1955 occurred with the passage of the Atlantic Coast Low as it moved inland and directly over the station. The second burst, occurring between 0900 and 1000 EST, October 15, accompanied the passage of the cold front.

The curve for Bridgeport, Conn., shows sustained and heavy rainfall throughout most of the period beginning at 2000 EST, October 14 and ending at 1400 EST, October 16. An examination of the surface charts shows that Bridgeport lay in the region of intense southeasterly flow just in advance of the occluded sector of the frontal system held virtually stationary by the blocking High to the northeast. The surface chart further shows the strong overrunning of the moist tropical air in this region.

The curve at Block Island, R. I. also shows the prolonged period of rainfall, which began at 2100 EST, October 14 and ended at 1600 EST, October 16, 1955. It is interesting to note that although Block Island, like Bridgeport, remained in the region of southeasterly flow, the precipitation there was light until the period 0100 EST, to 1400 EST, October 16, 1955. Between these times 6.34 inches of the total of 7.00 inches of rainfall for the station occurred. This was associated with the eastward movement of a Low on a track located just south of Block Island. This eastward movement of the Low accompanied the weakening of the block.

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